

9 a feedback circuit responsive to the voltage across the
10 common load;
11 control circuits for controlling the first and second pulse
12 width modulators responsive to the feedback circuit, the
13 operation of the first and second pulse width modulators being
14 interleaved;
15 the control circuits also being responsive to the difference
I 171,172 in currents [current] through the first converter and the second
17 converter to adjust the relative duty cycle of the first and
18 second converters to tend to minimize the difference in the
E 311,312 voltage across a [the] sense resistor;
20 [the current sense circuit,] the first pulse width
21 modulator, the second pulse width modulator, the feedback circuit
22 and the control circuits being in a single integrated circuit.

1 13. (Amended) The DC to DC switching circuit of claim 12
2 further comprised of an integrator having an output responsive to
3 the integral of an error signal, the error signal being
4 responsive to the voltage across the common load and a desired
5 voltage, the control circuits also being responsive to the output
I 6 of the integrator.

1 22. (New) A DC to DC converter having a plurality of
2 converter circuits for operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;

8 a plurality of pulse width modulators driven by a common
9 oscillator in an interleaved manner, each pulse width modulator
10 controlling one of the plurality of buck converter circuits,
11 whereby the operation of the buck converter circuits is
12 interleaved;

13 a feedback circuit responsive to a voltage across the common
14 load;

15 a voltage control circuit controlling the plurality of pulse
16 width modulators responsive to the feedback circuit and a
17 commanded output voltage; and

18 a current balance control circuit responsive to the
19 difference in currents in the plurality of interleaved buck
20 converter circuits and controlling the pulse width modulators to
21 balance the currents in the plurality of interleaved buck
22 converter circuits;

23 the plurality of pulse width modulators and the control
24 circuits being in a single integrated circuit.

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1 24. (New) The DC to DC converter of claim 22 further
2 comprised of an integrator having an output responsive to the
3 integral of an error signal, the error signal being responsive to
4 the voltage across the common load and a desired voltage, the
5 control circuits also being responsive to the output of the
6 integrator.

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1 25. (New) The DC to DC converter of claim 24 wherein a
2 time constant of the integrator is adjustable by the selection of
3 at least one component external to the integrated circuit.

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1 26. (New) The DC to DC converter of claim 24 further
2 comprised of a differentiator having an output responsive to the
3 rate of change of the voltage across the common load, the control
4 circuits also being responsive to the output of differentiator.

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1 27. (New) The DC to DC converter of claim 26 wherein the
2 time constant of the differentiator is adjustable by the
3 selection of at least one component external to the integrated
4 circuit.

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1 28. (New) The DC to DC converter of claim 22 wherein the
2 control circuits are also responsive to rapid decreases in the
3 voltage across the common load to turn on the plurality of buck

4 converter circuits independent of the phase of the plurality of
5 pulse width modulators.

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1 29. (New) The DC to DC converter of claim 28 wherein the
2 control circuits are also responsive to rapid increases in the
3 voltage across the common load to turn off the plurality of buck
4 converter circuits independent of the phase of the plurality of
5 pulse width modulators.

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1 30. (New) The DC to DC converter of claim 22, wherein the
2 plurality of pulse width modulators consist of a pair of pulse
3 width modulators.

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1 31. (New) The DC to DC converter of claim 22 wherein the
2 feedback circuit is in the single integrated circuit.

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1 32. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a plurality of pulse width modulators each controlling one
9 of the plurality of buck converter circuits, the operation of the

10 pulse width modulators and the buck converter circuits being
11 interleaved;
12 a feedback circuit responsive to a voltage across the common
13 load;
14 control circuits responsive to the feedback circuit and a
15 commanded output voltage to control a nominal duty cycle of the
16 plurality of buck converter circuits, the control circuits also
17 being responsive to the difference in currents in the plurality
18 of interleaved buck converter circuits to adjust relative duty
19 cycles of the plurality of buck converter circuits to balance the
20 currents in the buck converter circuits;
21 the plurality of pulse width modulators and the control
22 circuits being in a single integrated circuit.

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1 34. (New) The DC to DC converter of claim 32 wherein the
2 control circuits control the plurality of pulse width modulators.

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1 35. (New) The DC to DC converter of claim 32 further
2 comprising an integrator having an output responsive to the
3 integral of an error signal, the error signal being responsive to
4 the voltage across the common load and a desired voltage.

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1 36. (New) The DC to DC converter of claim 35, wherein the
2 control circuits are also responsive to the output of the
3 integrator.

27. (New) The DC to DC converter of claim 25 wherein a
time constant of the integrator is adjustable by the selection of
at least one component external to the integrated circuit.

18. (New) The DC to DC converter of claim 25 further
comprising a differentiator having an output responsive to a rate
of change of the voltage across the common load, the control
circuits also being responsive to the output of differentiator.

1 ~~39.~~ (New) The DC to DC converter of claim ~~38~~ wherein a
2 time constant of the differentiator is adjustable by the
3 selection of at least one component external to the integrated
4 circuit.

38 40. (New) The DC to DC converter of claim 32 wherein the
1 control circuits are also responsive to rapid decreases in the
2 voltage across the common load to turn on the plurality of buck
3 converter circuits, independent of the phase of the plurality of
4 pulse width modulators.

1 41. (New) The DC to DC converter of claim 32 wherein the
2 control circuits are also responsive to rapid increases in the
3 voltage across the common load to turn off the plurality of buck
4 converter circuits, independent of the phase of the plurality of
5 pulse width modulators.

1 40 1. (New) The DC to DC converter of claim 32, wherein the
2 plurality of pulse width modulators consist of a pair of pulse
3 width modulators.

1 41 1. (New) The DC to DC converter of claim 32 wherein the
2 commanded output voltage is controllable through an input to the
3 integrated circuit.

1 42 1. (New) The DC to DC converter of claim 32 wherein the
2 feedback circuit is in the single integrated circuit.

1 43 1. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;

8 a plurality of pulse width modulators each controlling one
9 of the plurality of buck converter circuits, the operation of the
10 pulse width modulators being interleaved;

11 control circuits for adjusting a nominal duty cycle of the
12 plurality of interleaved buck converter circuits, the control
13 circuits also being responsive to the difference in currents in

14 the plurality of interleaved buck converter circuits to adjust
15 the relative duty cycles of the plurality of buck converter
16 circuits to balance the currents therein;
17 the plurality of pulse width modulators and the control
18 circuits being in a single integrated circuit.

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1 46. (New) A DC to DC converter having first and second
2 converter circuits operating into a common load, comprising:
3 first and second buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a first pulse width modulator controlling the first buck
9 converter circuit;
10 a second pulse width modulator controlling the second buck
11 converter circuit;
12 a feedback circuit responsive to the voltage across the
13 common load;
14 control circuits for controlling the first and second pulse
15 width modulators responsive to the feedback circuit;
16 the control circuits also being responsive to current
17 measurements in the first buck converter circuit and the second
18 buck converter circuit for adjusting the relative duty cycle of

19 the first and second pulse width modulators to balance the
20 currents in the buck converter circuits;
21 the first pulse width modulator, the second pulse width
22 modulator, the feedback circuit and the control circuits being in
23 a single integrated circuit.

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1 41. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a plurality of pulse width modulators driven by a common
9 oscillator in an interleaved manner, each pulse width modulator
10 controlling one of the plurality of buck converter circuits,
11 whereby the operation of the buck converter circuits is
12 interleaved;
13 a feedback circuit responsive to a voltage across the common
14 load;
15 a voltage control circuit for controlling the plurality of
16 pulse width modulators responsive to the feedback circuit and a
17 commanded output voltage; and
18 a current balance control circuit responsive to the
19 difference in currents in the plurality of interleaved buck

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20 converter circuits for controlling the pulse width modulators to
21 balance the currents in the plurality of interleaved buck
22 converter circuits;
23 the plurality of pulse width modulators, the feedback
24 circuit, the voltage control circuit and the current balance
25 control circuit being in a single integrated circuit.

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1 46. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a plurality of pulse width modulators each controlling power
9 switching devices of one of the plurality of interleaved buck
10 converter circuits, the operation of the pulse width modulators
11 and the buck converter circuits being interleaved;
12 a feedback circuit responsive to a voltage across the common
13 load;
14 control circuits responsive to the feedback circuit and a
15 commanded output voltage to control a nominal duty cycle of the
16 plurality of buck converter circuits, the control circuits also
17 being responsive to the difference in currents in the plurality
18 of interleaved buck converter circuits to adjust the relative

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19 duty cycles of the plurality of buck converter circuits to
20 balance the currents in the buck converter circuits;
21 the plurality of pulse width modulators, the feedback
22 circuit and the control circuits being in a single integrated
23 circuit.

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1 49. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a plurality of pulse width modulators each controlling one
9 of the plurality of buck converter circuits, the pulse width
10 modulators being driven by a common oscillator signal so that the
11 operation of the pulse width modulators is interleaved;
12 control circuits for adjusting a nominal duty cycle of the
13 plurality of interleaved buck converter circuits to control a
14 voltage on the common load, and for responding to the difference
15 in currents in the plurality of interleaved buck converter
16 circuits to adjust the relative duty cycles of the plurality of
17 buck converter circuits to balance the currents in the buck
18 converter circuits;

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19 the plurality of pulse width modulators and the control
20 circuits being in a single integrated circuit.

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1 50. (New) A DC to DC converter having first and second
2 converter circuits operating into a common load, comprising:
3 first and second buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a first pulse width modulator controlling the first buck
9 converter circuit;
10 a second pulse width modulator controlling the second buck
11 converter circuit;
12 a feedback circuit responsive to the voltage across the
13 common load;
14 control circuits for controlling the first and second pulse
15 width modulators responsive to the feedback circuit;
16 the control circuits also being responsive to current
17 measurements through the first buck converter circuit and the
18 second buck converter circuit to adjust the relative duty cycle
19 of the first and second buck converter circuits
20 the first pulse width modulator, the second pulse width
21 modulator and the control circuits being in a single integrated
22 circuit.

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51. (New) A DC to DC converter comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between the first power supply terminal and the common load;

a plurality of pulse width modulators driven by a common oscillator in an interleaved manner, each pulse width modulator controlling one of the plurality of buck converter circuits, whereby the operation of the buck converter circuits is interleaved;

a feedback circuit responsive to a voltage on the common output;

a voltage control circuit for controlling the plurality of pulse width modulators responsive to the feedback circuit and a commanded output voltage; and

a current balance control circuit for controlling the pulse width modulators responsive to a difference in currents in the inductors of the plurality of interleaved buck converter circuits to balance the currents in the plurality of interleaved buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

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52. (New) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between the first power supply terminal and the common load, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling power switching devices of one of the plurality of buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits being responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits, the control circuits also being responsive to the difference in currents in the plurality of interleaved buck converter circuits to adjust the relative duty cycles of the plurality of buck converter circuits to balance the currents in the buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

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1 53. (New) A DC to DC converter having first and second
2 converter circuits operating into a common load, comprising:
3 first and second buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a first pulse width modulator controlling the first buck
9 converter circuit;
10 a second pulse width modulator controlling the second buck
11 converter circuit;
12 a feedback circuit responsive to the voltage across the
13 common load;
14 control circuits for controlling the first and second pulse
15 width modulators responsive to the feedback circuit;
16 the control circuits also being responsive to current
17 measurements in the first buck converter circuit and the second
18 buck converter circuit to adjust the relative duty cycle of the
19 first and second buck converter circuits;
20 the first pulse width modulator, the second pulse width
21 modulator, the feedback circuit and the control circuits being in
22 a single integrated circuit.

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2 54. (New) A DC to DC converter having a plurality of
3 converter circuits operating into a common load, comprising:
4 a plurality of buck converter circuits operating into the
5 common load, each buck converter circuit having an inductor for
6 alternately conducting between the first power supply terminal
7 and the common load, and the second power supply terminal and the
8 common load;

9 a plurality of pulse width modulators driven by a common
10 oscillator in an interleaved manner, each pulse width modulator
11 controlling one of the plurality of buck converter circuits,
12 whereby the operation of the buck converter circuits is
13 interleaved;

14 a feedback circuit responsive to a voltage across the common
15 load;

16 a voltage control circuit for controlling the plurality of
17 pulse width modulators responsive to the feedback circuit and a
18 commanded output voltage; and

19 a current balance control circuit for controlling the pulse
20 width modulators to balance the currents in the plurality of
21 interleaved buck converter circuits responsive to the difference
22 in currents in the plurality of interleaved buck converter
 circuits;

23 the plurality of pulse width modulators, the voltage control
24 circuit and the current balance control circuit being in a single
25 integrated circuit.

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1 55. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a plurality of pulse width modulators each controlling power
9 switching devices of one of the plurality of interleaved buck
10 converter circuits, the operation of the pulse width modulators
11 and the buck converter circuits being interleaved;
12 a feedback circuit responsive to a voltage across the common
13 load;
14 control circuits responsive to the feedback circuit and a
15 commanded output voltage to control a nominal duty cycle of the
16 plurality of buck converter circuits, the control circuits also
17 adjusting relative duty cycles of the plurality of buck converter
18 circuits to balance the currents in the buck converter circuits
19 responsive to the difference in currents in the plurality of
20 interleaved buck converter circuits;

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21 the plurality of pulse width modulators and the control
22 circuits being in a single integrated circuit.

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1 58. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;

8 a plurality of pulse width modulators each controlling one
9 of the plurality of buck converter circuits, the pulse width
10 modulators being driven by a common oscillator signal so that the
11 operation of the pulse width modulators is interleaved;
12 control circuits for adjusting a nominal duty cycle of the
13 plurality of interleaved buck converter circuits to control a
14 voltage on the common load, and for adjusting relative duty
15 cycles of the plurality of buck converter circuits to balance the
16 currents in the buck converter circuits;

17 the plurality of pulse width modulators and the control
18 circuits being in a single integrated circuit.

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1 57. (New) A DC to DC converter having first and second
2 buck converter circuits operating into a common load, comprising:
3 first and second buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;

8 a first pulse width modulator controlling the first buck
9 converter circuit;

10 a second pulse width modulator controlling the second buck
11 converter circuit;

12 a feedback circuit responsive to the voltage across the
13 common load;

14 control circuits for controlling the first and second pulse
15 width modulators responsive to the feedback circuit;

16 the control circuits also being responsive to current
17 measurements in the first buck converter circuit and the second
18 buck converter circuit to adjust the relative duty cycle of the
19 first and second pulse width modulators to balance the currents
20 in the buck converter circuits;

21 the first pulse width modulator, the second pulse width
22 modulator and the control circuits being in a single integrated
23 circuit.

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1 58. (New) A DC to DC converter having a plurality of
2 converter circuits for operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;

8 a plurality of pulse width modulators driven by a common
9 oscillator in an interleaved manner, each pulse width modulator
10 controlling one of the plurality of buck converter circuits,
11 whereby the operation of the buck converter circuits is
12 interleaved;

13 a feedback circuit responsive to a voltage across the common
14 output;

15 a voltage control circuit controlling the plurality of pulse
16 width modulators responsive to the feedback circuit and a
17 commanded output voltage;

18 the plurality of pulse width modulators and the control
19 circuits being in a single integrated circuit.

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1 59. (New) The DC to DC converter of claim 58 further
2 comprising the common oscillator, the common oscillator also
3 being in the single integrated circuit.

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1 60. (New) A DC to DC converter having a plurality of
2 converter circuits operating into a common load, comprising:
3 a plurality of buck converter circuits operating into the
4 common load, each buck converter circuit having an inductor for
5 alternately conducting between the first power supply terminal
6 and the common load, and the second power supply terminal and the
7 common load;
8 a plurality of pulse width modulators each controlling one
9 of the plurality of buck converter circuits, the operation of the
10 pulse width modulators and the buck converter circuits being
11 interleaved;
12 a feedback circuit responsive to a voltage across the common
13 load;
14 control circuits responsive to the feedback circuit and a
15 commanded output voltage to control a nominal duty cycle of the
16 plurality of buck converter circuits;
17 the plurality of pulse width modulators and the control
18 circuits being in a single integrated circuit.

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1 61. (New) The DC to DC converter of claim 60 further
2 comprising the common oscillator, the common oscillator also
3 being in the single integrated circuit.

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1 62. (New) A DC to DC converter comprising:

2 first and second buck converter circuits operating into a
3 common load, each buck converter circuit having an inductor for
4 alternately conducting between the first power supply terminal
5 and the common load, and the second power supply terminal and the
6 common load;

7 first and second pulse width modulators driven by a common
8 oscillator in an interleaved manner, each pulse width modulator
9 controlling a respective one of the first and second buck
10 converter circuits, whereby the operation of the buck converter
11 circuits is interleaved;

12 a feedback circuit responsive to a voltage across the common
13 output;

14 a voltage control circuit controlling the first and second
15 pulse width modulators responsive to the feedback circuit and a
16 commanded output voltage;

17 the plurality of pulse width modulators and the control
18 circuits being in a single integrated circuit.

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1 62. (New) The DC to DC converter of claim 62 further
2 comprising the common oscillator, the common oscillator also
3 being in the single integrated circuit.

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64. (New) A DC to DC converter comprising:

first and second buck converter circuits operating into a common load, each buck converter circuit having an inductor for alternately conducting between the first power supply terminal and the common load;

first and second pulse width modulators each controlling a respective one of the buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

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65. (New) The DC to DC converter of claim 64 further comprising the common oscillator, the common oscillator also being in the single integrated circuit.